Depth-Resolved Photoemission Spectroscopy with Soft X-ray Standing Wave: Observation of depth specific dependence on buried layers

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INTRODUCTION

The x-ray standing wave technique has been extensively exploited to study the structural and chemical properties of thin films as well as various surfaces[1,2,3]. Especially, the relatively high energy x-ray standing waves have been a great tool to determine the interlayer spacing for a few top-layers for ordered crystals by resorting to the Auger[4] or X-ray fluorescence spectroscopies[5] or extended x-ray absorption fine structure (EXAFS)[6]. Also some photoemission spectroscopy using standing wave technique have been done with high energy or hard x-rays for the study of bonding structures[7]. Meanwhile, recently the soft x-ray region has attracted huge attention of experimentalists working on the magnetic and electronic properties on magnetic materials because the absorption edge for magnetic materials, e.g. transition or rare-earth metal compounds, are mostly located in soft x-ray range.

EXPERIMENTAL

The standing wave periodic multilayer (SWPM) wafer has been prepared by magnetron-sputtering method in the center for x-ray optics (CXRO) at Lawrence Berkeley National Laboratory. The SWPM is composed of alternate layer B_4C/W (number of repetition=40) on SiO_2 substrate. The structural parameters and reflectivities have been measured by x-ray reflectometer equipped with rotating copper anode gun ($h\nu$=8051 eV); the period, reflectivity and interdiffusion length (σ) turned out to be 39.6 , 0.81 and 2.4 , respectively. And the ratio of W thickness to period was simulated as 0.432 (d_{B4C}=22.49 , d_W=17.11 . The spectroscopy measurements were performed on bend-magnet beam line 9.3.2[8] at the Advanced Light Source utilizing a photoelectron spectrometer/diffractometer based on a Scienta ES-200 photoelectron analyzer. Small size of beam (less than 500 μm) made it possible for us to get high angular (~0.5°) and depth-resolved spectra. 68° was the angle between incidence photon angle and photoelectron take-off one. The base pressure was 9×10^{-11} Torr and each group bundling all element spectral sets was obtained within one refill span in order to get systematic reliable data. And the linear p-polarization of photon has been used throughout the experiment.

RESULTS AND CONCLUSION

A new type of soft x-ray photoemission spectroscopy is carried out in which depth sensitivity is provided by means of a periodic multilayer ($(B_4C(22.49\ )/W(17.11\ ))_{40}/SiO_2$ that possesses sizeable standing wave effects. Using synchrotron radiation soft x-rays at $h\nu$=750 eV it is observed that the photoelectron intensities of each element are sharply altered when the incidence x-ray is tuned over the Bragg condition. In addition, the angular dependencies of photoelectron intensity show unique behavior depending on chemical environment as well as configuration of buried layers. Depth-resolved photoemission with soft x-ray standing wave should be a very useful tool for studying the interfacial electronic and magnetic properties.

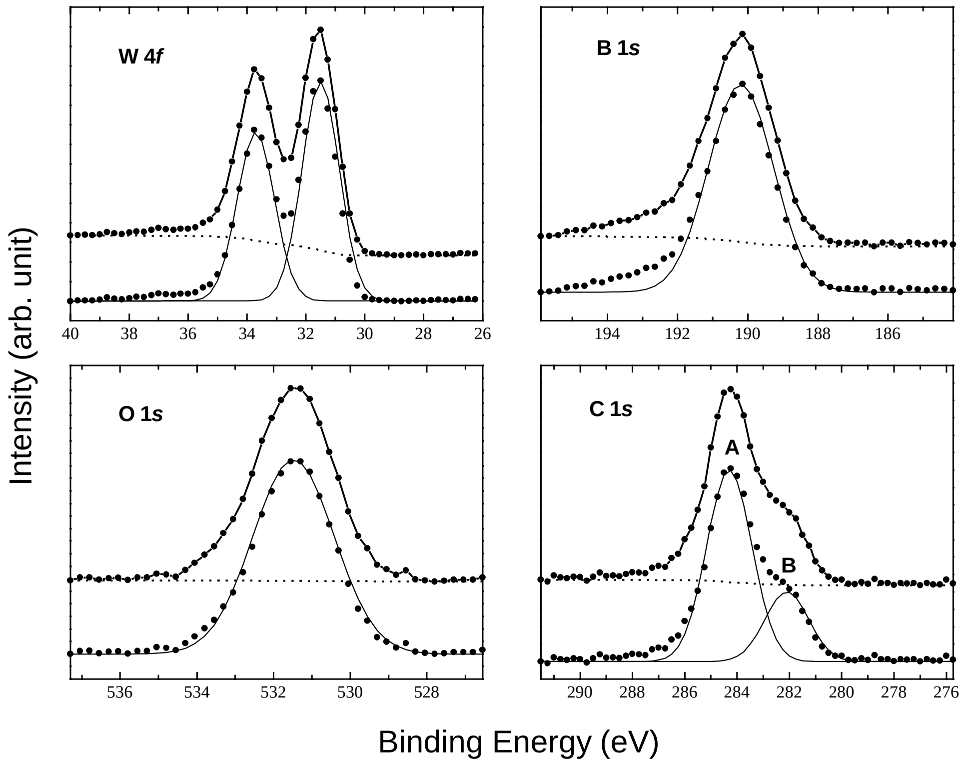

Figure 1. Core-level photoemission spectroscopy for W 4*f*, B 1*s*, O 1*s* and C 1*s* in (B_4C(22.49)/W(17.11))$_{40}$/SiO_2. The photon energy, incidence photon angle and photoelectron take-off angle are 750 eV, 7.85°and 75.85°, respectively. The background subtraction and Voigt function fits are also presented. It is shown that C 1*s* possesses two feature A and B.

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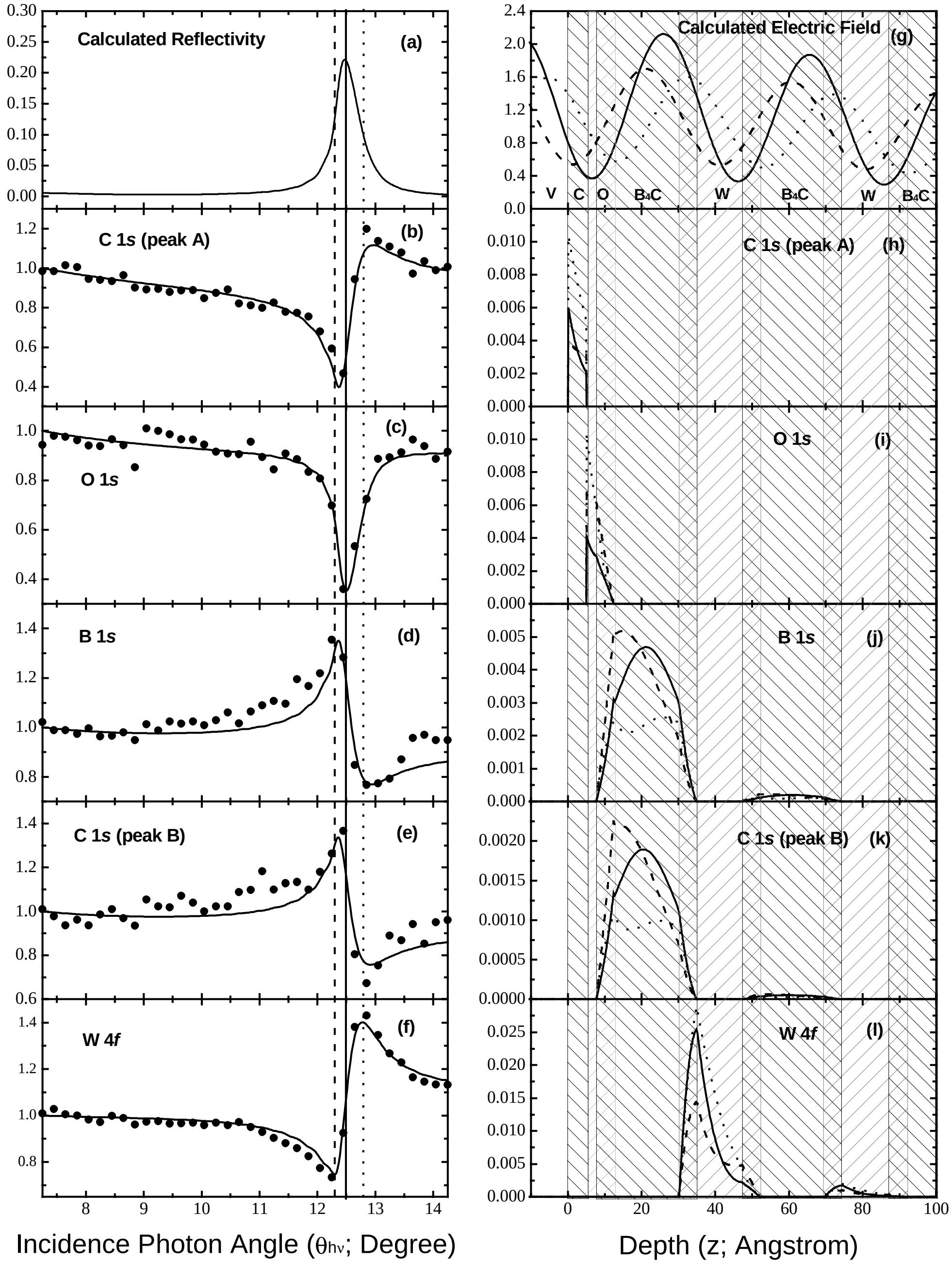

Fig.2 S.-H. Yang et al.

Figure 2. The incidence photon angle scan of photoelectron intensity together with theoretical simulation. The calculated reflectivity is shown in (a) indicating Bragg position (12.48°).